

GROUND SHAKING

John Farish, a mining engineer, was staying at the St. Francis hotel pictured below when the earthquakes started about 5:15 am in San Francisco on Wednesday, April 18, 1906. Below is his recollection of that day. John Farish, a mining engineer, was staying at the St. Francis hotel pictured below when the earthquakes started about 5:15 am in San Francisco on Wednesday, April 18, 1906. Below is his recollection of that day. *"I was awakened by a loud rumbling noise which might be compared to the mixed sounds of a strong wind rushing through a forest and the breaking of waves against a cliff. In less time than it takes to tell, a concussion, similar to that caused by the nearby explosion of a huge blast, shook the building to its foundations and it began a series of the most lively motions imaginable. Accompanied by a creaking, grinding, rasping sound, it was followed by tremendous crashes as the cornices of adjoining buildings and chimneys tottered to the ground."*



<http://www.exploratorium.edu/faultline/1906/>
Photo credit: Steinbrugge Collection, Earthquake Engineering Research Center,
University of California, Berkeley

U.S. Weather Service forecaster Alexander McAdie recorded the times of the tremors, an account published in the *San Francisco Chronicle* on April 24, 1906.

The first one occurring at 5:13 o'clock in the morning lasted forty-seven seconds. Another one came at 5:18 and lasted a few seconds; another came at 5:20 another at 5:25, another at 5:42, and then came a lapse until 8:13. This shock lasted five seconds as was the most severe since the big shake-up. The occurrence of the following shocks came at 9:13, 9:25, 10:49, 11:05; 12:03, 12:10, 2:23, 2:27, 4:50, 6:49 and 7 o'clock.

The great movement of the earth in the bay region can hardly be said to be over. McAdie says that he has records of numbers of shocks for every day since the fateful Wednesday but he hastens to assure the public that the danger from heavy shock of a destructive character is gone. The minor temblors which

are still coming and one of which occurred at an early hour yesterday morning, are merely the necessary movements of the earth in the process of adjustment. They will come at greater intervals and grow weaker until they become absolutely imperceptible. <http://www.sfmuseum.net/press/clips13.html>

Both of these accounts are about the Great San Francisco Earthquake, which ranks as one of the most significant earthquakes of history. This earthquake affected about 290 miles (470 km) of the Earth's surface and was felt from Oregon to just south of Los Angeles, California. The violent shocks sparked a catastrophic fire that burned for days and, most importantly, sparked a community of scientists to learn more about earthquakes.

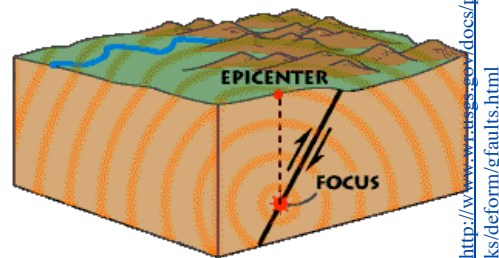
What are earthquakes and what causes them?

<http://earthquake.usgs.gov/fac/effects.htm>



An earthquake is a rapid shaking of the ground caused by the release of energy stored in the rocks of the Earth. When the hot, asphalt-like mantle changes and moves, so do the Earth's cool plates. The movement of Earth's plates can cause stress and strain on these rigid plates. This stress and strain can build up pressure in the layers of rock in the crust. This stress causes rocks to bend, squeeze, or break. When the stress and pressure are great enough, they are released in one quick event, an **earthquake**. Where several of these earthquakes occur, a crack develops. We call this crack a **fault**. (This may be a different meaning from the "fault" that you know. It's one of the many words that people have an

everyday meaning for which also has a special meaning in science.) In places where there are volcanoes, the shifting mantle causes earthquakes also. When the mantle moves, the ground shakes.



<http://www.usgs.gov/docs/par/ks/deform/gfaults.html>

Where does the earthquake start?

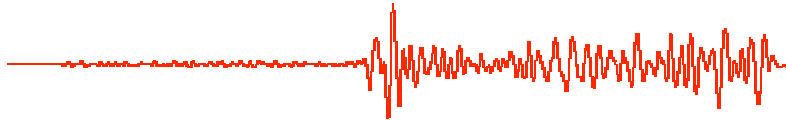
The **focus** is the point under the earth where the earthquake starts and the energy is released. The **epicenter** is the point on the surface of the Earth directly above the focus. The epicenter of an earthquake is important. While the shock waves from an earthquake can be detected around the world, most of the damage occurs at the epicenter, or close to it.

How does the force of the earthquake travel through the Earth?

Imagine that you have dropped a large rock in a bucket of water. You can see the vibrations in the rippling of the water on the surface. Imagine you dropped that large rock again but this time you put your hand on the bottom of the bucket before you dropped the rock. You can feel the vibrations of the rock hitting the surface of the water. You can feel the vibrations the rock makes because its energy travels through the water.

The energy from an earthquake moves in much the same way; it travels out from the center in wave-like patterns called **seismic waves**. Some of these seismic waves travel on the surface, like the ripples you can see in the water, and some travel through the Earth, like the vibrations you

could feel on the bottom of the bucket. The **surface waves** can travel thousands of miles from the epicenter of an earthquake, and they can cause lots of damage. Like the waves that moved through the bucket of water, some of these waves travel through the Earth instead of on its surface. We call these **body waves**.



<http://quake.wr.usgs.gov/info/1906/seismogram.html>

The seismic waves from the 1906 earthquake in San Francisco were felt some 9,100 miles (14642 km) away in Gottingen,

Germany. Above is the record from a **seismograph** (an instrument used to record waves from earthquakes). The part of the record shown here spans about 26 minutes. Only body waves are shown in this record. When surface waves arrived later, the instrument went off-scale (that means the waves were larger than the seismograph could record).

In 1989, an area near San Francisco called Lom Prieta was hit with another large earthquake. Highways collapsed, buildings crumbled, and fires began once again. Because this area was more populated than in 1906, this earthquake caused more damage, even though the ground shook more in the earlier earthquake. Below is a seismograph recording from the 1989 earthquake. The same seismograph that recorded the 1906 earthquake was there to record the 1989 earthquake.



Lom Prieta, California 1989

http://wrgis.wr.usgs.gov/dds/dds-29/web_pages/sf.html



http://quake.wr.usgs.gov/info/1906/got_seismogram_lp.html

The following are 9-1-1 recordings from immediately after the 1989 Lom Prieta earthquake in the San Francisco area.

This call began moments before the first large aftershock.

Dispatcher: 911 Emergency.

Caller: My whole house is tore up! Should I take my kids outside?

Dispatcher: Your whole house what?

Caller: It's tore up! Everything's tore up, should I take my kids outside?

Dispatcher: Yeah, that would be a good idea because here comes another one!

<http://www.sfmuseum.org/1906/89.html>

This call was received on the direct line from the Highway Patrol office. CHP stands for California Highway Patrol. When the officers say "280," they are referring to the name of the highway.

CHP: We're losing 280. We need all the ramps to 280 closed, if you've got any available units close the traffic coming on to 280 extension up by Sixth Street. It's going down.

Dispatcher: What's going down? The ramp is?

CHP: The ramp is. It's collapsing!

Dispatcher: Okay, hold on, I'll tell 'em right now.

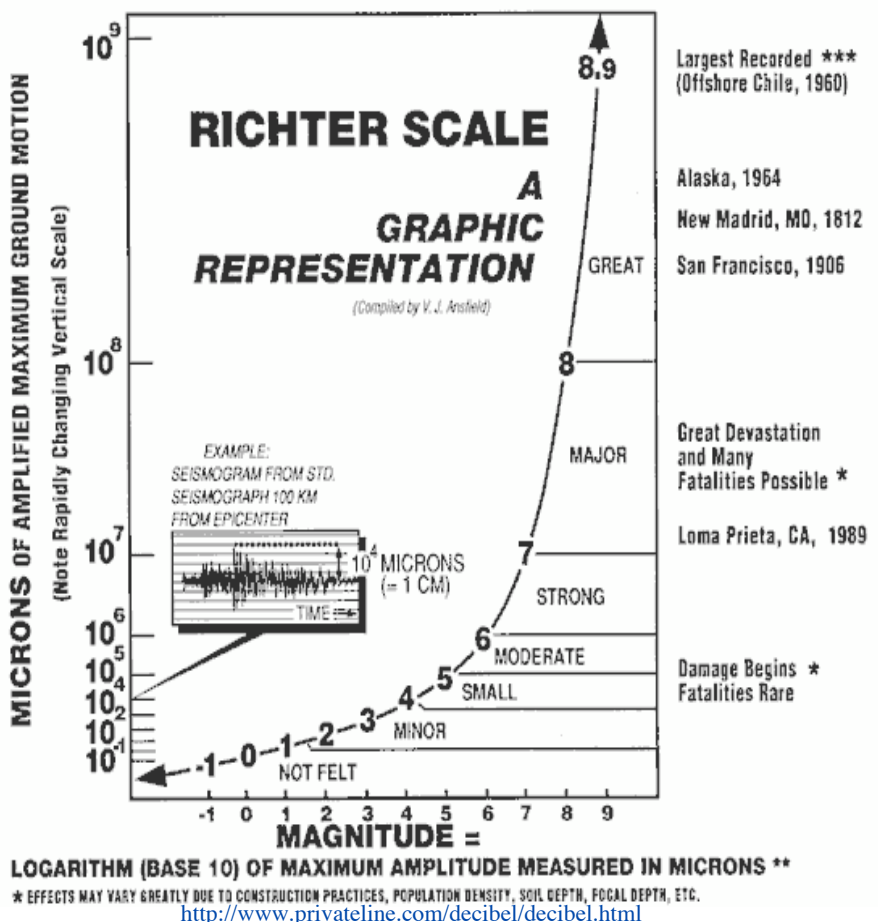
CHP: Thank you

<http://www.sfmuseum.org/1906/89.html>

How is the strength of an earthquake measured?

The newspaper headline read, "*Strong 7.9 Quake leaves Peru reeling Arequipa hardest hit; at least 52 dead.*" You can probably tell from the headline that this was a large and destructive earthquake. But, what does that 7.9 mean?

The 7.9 is the earthquake's **magnitude**, a measure of how much energy an earthquake has released. In the United States we use the **Richter Scale** to



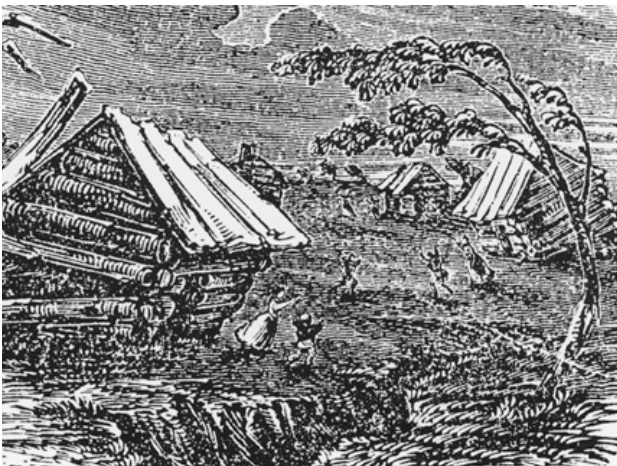
measure magnitude. The Richter Scale ranges from 1 to 9 with 1 being small earthquakes and 9 being large earthquakes. On the Richter Scale, earthquakes with a magnitude of 1 or 2 are small and cannot be felt by people. These small earthquakes are often not reported because they can be the result of a building being demolished as well as of a movement of the crust. Earthquakes with a magnitude of 3 or 4 are sometimes felt but are still considered small earthquakes. Earthquakes with medium magnitudes (4 to 6) are always felt and result in minor damage. Earthquakes with magnitudes larger than 6 are felt by everyone, and there is much damage and devastation.



Stop and Think

Make a prediction. How destructive an earthquake is depends on several factors. The size of the earthquake on the Richter Scale is only one factor. What else do you think might affect how destructive an earthquake is?

Size is not all that matters! In late 1811 and early 1812, New Madrid, Missouri was the



site of a series of the largest and most geologically significant earthquakes in U.S. history. It is told that church bells tolled in Boston, and that the Mississippi River reversed flow and changed course. It is also told that fields were swallowed up, and new lakes were formed, all from this series of earthquakes. In 1812 this part of the country was scarcely populated or populated by people that did not read or write, so stories have been passed down through the generations and surely retold with a little more flavor. Though the personal devastation

was not significant, the geological changes were.

What made these earthquakes shake so much more than many other earthquakes is the geology of the area. Thousands of years of sediment have built up in this region from glaciations and old ocean bottoms. Think of a plate of gelatin. If you shake the plate the top of the gelatin really shakes. The ground in New Madrid, with all the sediment, reacted to the earthquake much like the gelatin does when you shake it. An earthquake happening in these conditions causes more ground motion and therefore more devastation. In the San Francisco earthquake, people noticed the most devastation in parts of the city that were built on reclaimed land from the San Francisco Bay. The shaking of this soft sediment results in more damage.

Since the geological conditions of the area play a role in the destruction of an area hit by an earthquake, seismologists use a separate method to estimate the **effects** of an earthquake, called its **intensity**. **Intensity** should not be confused with **magnitude**. When scientists measure the intensity of an earthquake, they are trying to determine the effects of the quake at a particular place. The **intensity**, or amount of damage, is determined by observing the effects on the local people, the buildings, and the Earth's surface. To report intensity, seismologists use the